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Stability of mantle control over dynamo flux since the mid-Cenozoic

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ABSTRACT

Studies of paleomagnetic fields during polarity transitions recorded over the past few million years frequently suggest a configurational persistence consistent with long-lived mantle control over the pattern of flux emanating from Earth's fluid core. Fundamental to an understanding of the core–mantle dynamics involved is the question of the spatial-temporal nature of the physical conditions at the base of the mantle that may be responsible. Our analysis of the field during a mid-Cenozoic, reverse-to-normal (R–N) polarity change, recorded in a continuous sequence of lava flows in southeastern Queensland, Australia, provides strong evidence that the time span over which local mantle features retain such an influence is far longer than had thus far been observed. Specifically, the reversal is dominated by two sequential groupings of transitional magnetic vector directions, each associated with a clustering of virtual geomagnetic poles (VGPs) at locations common to several more youthful reversal datasets from about the globe. Our $^{40}Ar/^{39}Ar$ age determinations indicate that these Australian lavas erupted 25.56 ± 0.48 Ma, strongly suggesting that the characteristic time for invariant control by the mantle over flux emerging from the outer core is at least on order of a few tens of Myr. The availability of transitional paleomagnetic data from still earlier times within the Cenozoic may further delineate this duration and, perhaps, provide a means to track changes in the pattern of long-standing concentrations of magnetic flux at the core–mantle boundary.

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1. Introduction

Recordings of the ambient geomagnetic field in rocks during polarity reversals and other geomagnetic events – i.e., at those times when the axial dipole component of the field has significantly weakened – have been found to provide, perhaps, the most easily identifiable paleomagnetic data relevant to the investigation of possible mantle influence over the geodynamo (e.g. Laj et al., 1991; Clement, 1991; Hoffman, 1992; Constable, 1992). For example, clusters of transitional VGPs in and around western Australia are common both to the five records of reversals and events spanning the past 3 Myr obtained from lavas erupted at the Society Islands hot spot (Roperch and Duncan, 1990; Chauvin et al., 1990; Hoffman and Singer, 2004) as well as to several records of the last reversal of the geomagnetic field obtained from sites about the globe (Hoffman, 2000; Brown et al., 2004). Moreover, it has been shown that an inordinately large fraction of Earth's surface would experience vector field directions corresponding to Australasian south VGPs if the axial dipole of the modern-day field were to vanish (Hoffman and Singer, 2004). The likely explanation for these particular correspondences is that the heterogeneity of the lower-most mantle appears to have held a concentration of magnetic flux, presently at the top of the core off the west coast of Australia (Jackson et al., 2000), in a manner that has remained essentially unchanged since the Pliocene. If so, then analyses of transitional field behavior recorded in rocks from Australasia – i.e., the region on Earth's surface in closest proximity to this area of the core surface – would be expected to provide the clearest observations of any spatial-temporal changes that may be associated with modifications of the local pattern of mantle-held flux.

Along the Quamby Falls creek bed near Natural Bridge National Park in southeast Queensland, Australia, we sampled some 30 flows over a 200-m thick continuous section (Fig. 1) of a far thicker stack of Tweed Volcano basalts (see Johnson, 1989) (28.2°S, 153.2°E). The age of the complete sequence, determined in the mid-1970s by the K–Ar method, was found to be in the range 22–20 Ma (Wellman, 1975). However, our more precise $^{40}Ar/^{39}Ar$ age determinations find the eruptive activity to be significantly older than this.

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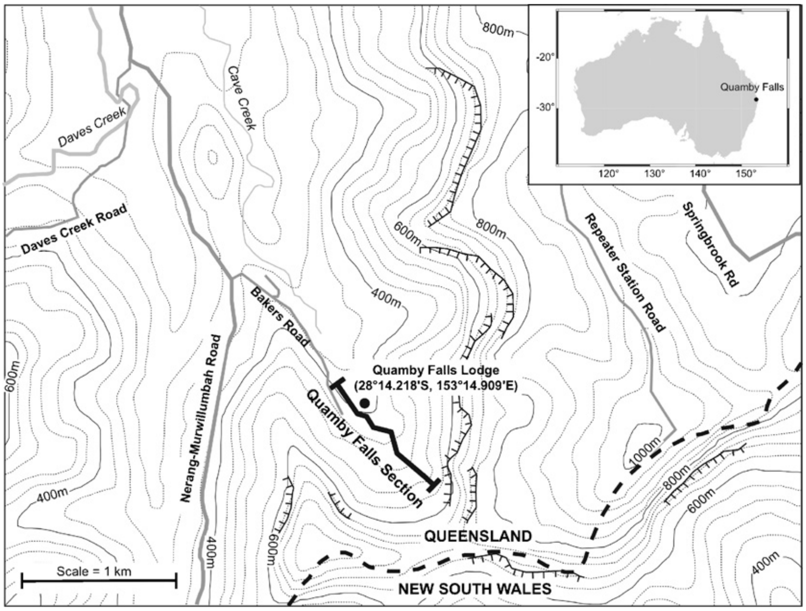

Fig. 1. Sampling site map along Quamby Falls Creek near Natural Bridge, Queensland, Australia.

2. ^{40}Ar/^{39}Ar age determinations

Groundmass separates of 3 mg each from 10 of the lava flow sites were incrementally heated in 12 steps using a 25 W CO_2 laser at the University of Wisconsin-Madison Rare Gas Geochronology Laboratory. Mass spectrometry and calculation of ages from these experiments follow procedures found in Smith et al. (2006). The age spectra range from concordant (100% of gas defining a plateau) to strongly discordant, with one sample (QF-14) failing to yield a meaningful plateau age. Most other samples yielded spectra with discordant low-temperature steps comprising between 10% and 60% of the gas (Fig. 2). This most likely reflects variable alteration of the basalt matrix. Although many of the isochrons do not give precise ^{40}Ar/^{36}Ar intercept values, there is no evidence that excess argon is present in any of these lavas (Table 1).

Notwithstanding the discordant nature of many spectra, the plateau segments from 9 of the samples yield isochron ages ranging from 26.41 ± 0.91 to 23.53 ± 3.02 Ma which, given the 2σ analytical precisions are indistinguishable from one another. Since the lavas record a R–N polarity transition in a continuous exposed sequence, we have pooled the isochron ages of these 9 samples. The weighted mean of the nine isochrons is 25.56 ± 0.48 Ma (MSWD = 1.4), and

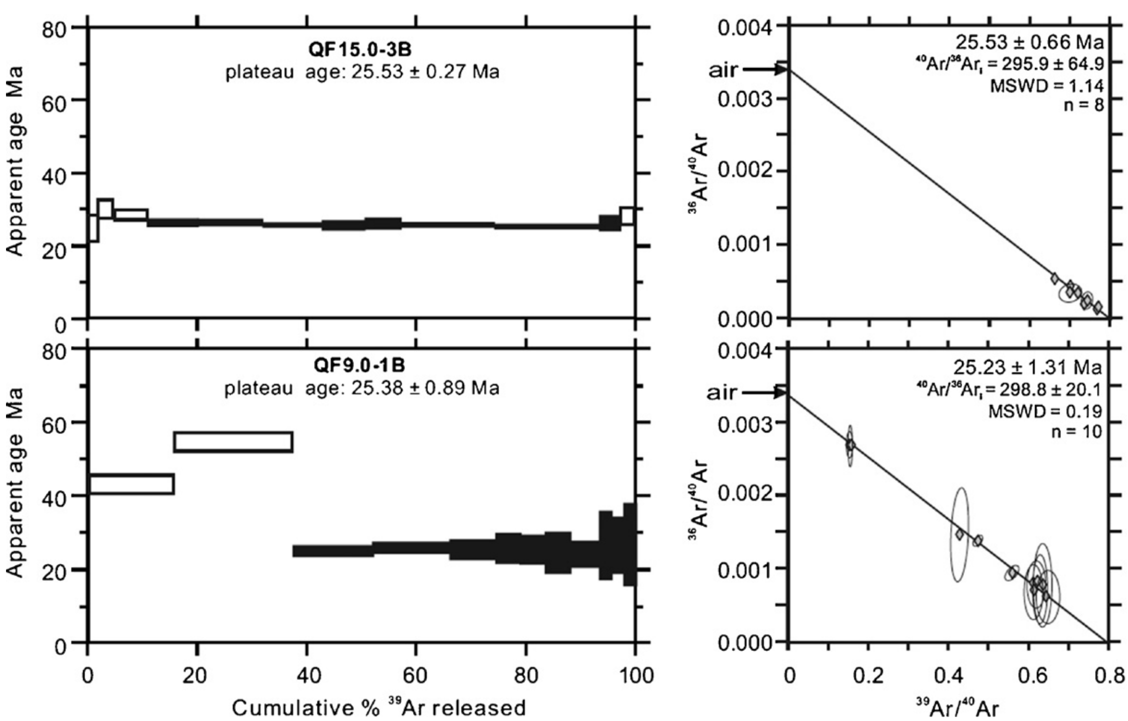

Fig. 2. ^{40}Ar/^{39}Ar age spectrum (left) and isochron (right) diagrams for Quamby Falls flow sites 15.0-3B and 9.0-1B. The isochrons are regressed from the plateau data illustrated as dark filled boxes in the age spectra and give the preferred age for these lava flows.

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